U.S. Department of the Interior
U.S. Geological Survey

*The National Map* Catalog Technical Discussion Paper

# Reliability of *The National Map* Web Map Services

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*With October 2003 update*

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# Abstract

Automatic software to monitor the availability of Web Map Services (WMS) that contribute to *The National Map* was implemented in the Catalog in late July, 2003. 7 weeks of data collected by this software show that most of the current 39 WMSs of *The National Map* have apparently high levels of reliability.

- 34 WMS have availability greater than 90%.
- 21 WMSs have availability greater than 98%.

Although this is good news, it is just one piece of a larger picture. It is not clear that even 98% reliability is adequate in the long run. Further, WMS availability is just one of many factors, mostly unstudied at this time, that contribute to *The National Map* availability.

Service availability can be monitored continuously from now on. The data from this monitoring provide a starting point for discussions about reliability requirements of *The National Map*.


# 1 Introduction

The technological foundation of *The National Map* implementation is the OGC Web Map Services (WMS) standard. The meaning of this statement is explained in detail in other documents, several of which are listed in the references section.

## *1.1 The 24/7 Problem*

Simply put, *The National Map* depends on data served by other organizations in real time. These **partners** maintain WMSs that deliver data to USGS applications through a standard interface. The systems that host the data and WMSs are owned by partner organizations. When these systems are down, partners' data become unavailable to *The National Map* applications.

This is a ubiquitous problem in the world of distributed data management and Internet data delivery, but it is a new problem for the USGS National Mapping Program. In the past, our data production and delivery systems have been 1) mostly static and 2) completely under our control. When a system went down for a few hours or days, few outsiders noticed or cared. This is obviously not true of *The National Map*, which aspires to be a 24/7 system that follows the model of (for example) Google or MapQuest, not the model of traditional topographic mapping.

The overall reliability of *The National Map* is an extremely complex issue, and this report does not attempt to address the general problem. The scope of this report is one specific but significant issue, the reliability of the Web Map Services that feed data to *The National Map* applications.

## *1.2 What is "WMS reliability?"*

From the end user's perspective, the public viewer at http://nationalmap.usgs.gov/nmjump.html **is** *The National Map*. Behind this user interface a great deal is happening, but the gory details are not visible. The main point of *The National Map* is to present an apparently seamless, single-source map. The complexity of assembling this map from a large number of distributed sources is deliberately hidden.

Suppose the USGS has a partnership agreement with the lead GIS organization in StateX. This partner owns a WMS and serves the best available data for several themes.

To achieve 100% reliability, computer systems must have massive redundancy in power source, hardware, and software. These conditions basically do not yet exist in the GIS community. If the StateX WMS is unresponsive due to a local power failure, its data will not be available to *The National Map*. Worse, *The National Map* applications have no way to know what is wrong; they can only know that the service they are trying to query is not responding.[1]

For the purposes of this discussion**, WMS reliability** or **availability** is defined as the percentage of time that a particular WMS responds correctly to well-formed queries.[2]

# 2 The Catalog Service Checker

The need to quantify WMS reliability was recognized early in the development of *The National Map* viewers. The deployment of the Catalog in May 2003 made it possible to monitor the WMSs, and the deployment of the Catalog-enabled Phase D viewer made this monitoring relevant. In July 2003 Jeff Wendel wrote a "service checker" program that runs continuously on the system that provides the Catalog services.

The checker loops through all the WMSs listed in the Catalog and "pings" each one by issuing an OGC WMS query. It then evaluates the answer to see if a legal response came from the WMS. If the answer is *yes*, the system is considered available. If the response is anything else (e.g., an error message from an operating system or the Internet routing system), the WMS is considered unavailable. The time of the check, the WMS id number, and the availability status are stored in an Oracle table in the Catalog.

Note that this mechanism does not prove failure of the WMS. In any given instance of failure, the fault could be somewhere in the USGS or Internet systems between the service checker and the WMS. However, the distributions of failure data presented in this report indicate that failure at the WMS is probably a reasonable hypothesis much of the time.

The checker is a low-priority process that runs in the background, so the time between checks varies. The overall average after nearly two months of operation is 90 pings per service per day. 280,000 records were recorded for 3,140 service-days between August 6 and September 22.

Because each check is a point-in-time measurement, the data for one service during any one hour may not be very meaningful. But with 90 pings per service per day, enough data are being collected to approximate continuous monitoring over longer time periods.

# 3 Results of Service Monitoring

Figure 1 is a low-resolution graphic representation of service availability between August 6 and September 22, 2003. The data in the image are only for services marked "public" in the catalog.[3]

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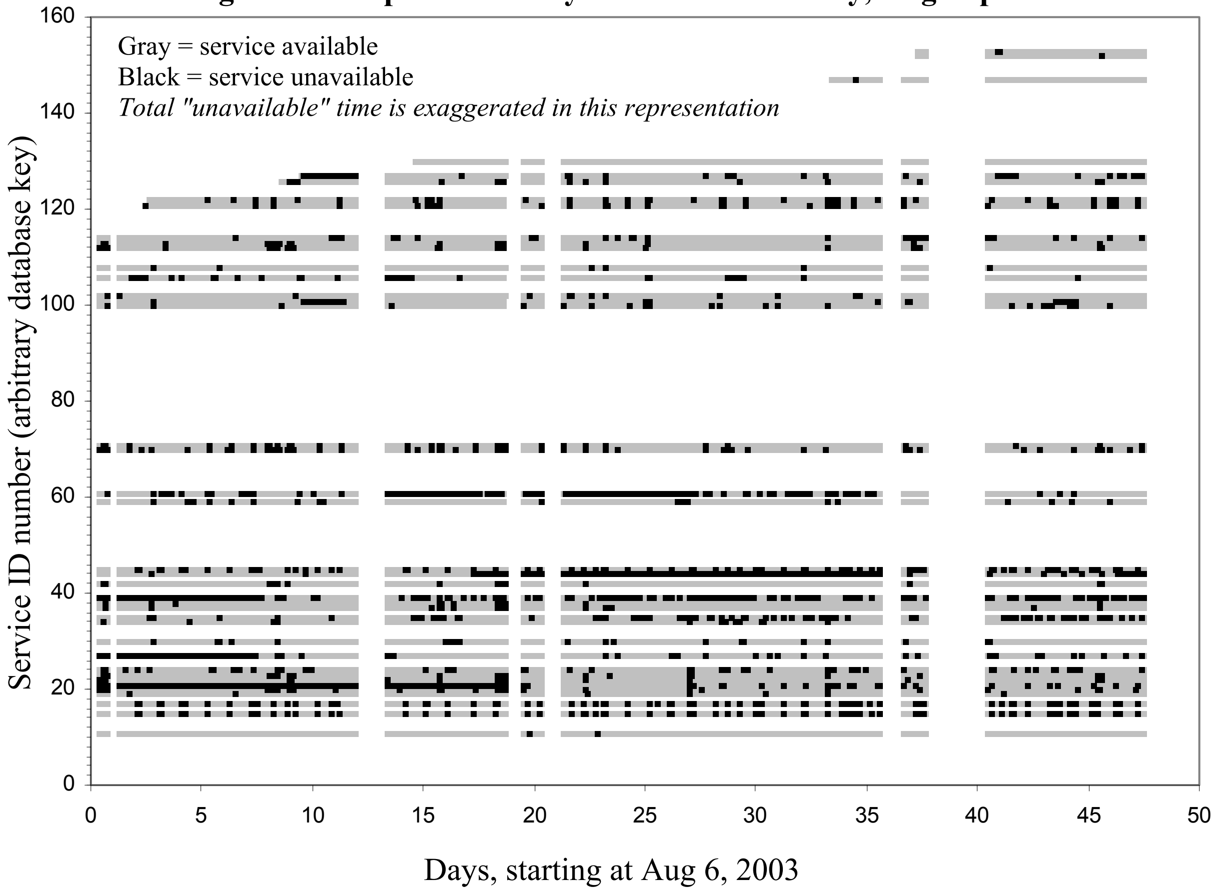
[1] The behavior seen by the end user in this case depends on several things, including the sophistication of error trapping in *The National Map* applications, but also possibly on things beyond the control of these applications, such as timeout thresholds of operating systems or even the user's brand of Web browser.

[2] This is an ad-hoc definition for use in this paper only. "Web Services Reliability" has more highly defined and technical meanings within the Web-based business community. See, for example, http://www.appdevadvisor.co.uk/Bulletins/XMLWEB_SERVICES/main.htm. In much of the literature "reliability" is not the same as "availability." More study of existing standards and conventions is needed.

**Figure 1. Graphic summary of WMS availability, Aug-Sept 2003**




Non-public services are not visible through *The National Map* viewer and are omitted from these summary data.

Each non-white pixel in the image is a point where a service was checked. Each gray point represents a time when a service was available; each black point represents a time when a service was not available.

A horizontal "line" of gray and black points is therefore the availability record for a particular service. Black points along these lines are times where the service was not available. The vertical white "lines" are no-data areas, generally times when the service checker software was not operating. At this time the service checker software is less reliable than most of the WMSs it is monitoring; if these data are useful for long-term monitoring, the reliability of the checker will need to be improved. Horizontal white space represents database id numbers that are not associated with any WMS that is used to show data in *The National Map* viewer.

The data resolution is greatly reduced in this graphic. Because of this, and because the black points are printed on top of the gray points, the ***total time of service unavailability is visually exaggerated in Fig 1***. The graphic should not be used to quantify service availability, but only to visualize general trends.

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[3] An unrelated by interesting point illustrated by the graphic is that very few new data partners (highest-number service IDs) were acquired during this period.

Fig 2 is a different representation of the data, at a higher resolution, but for a single service. The service in Fig 2 is **USGS Ref WMS (RMMC new)** (service id 35, Table 1 and Attachment A), the service that delivers much of the small-scale reference data for *The National Map*. As with Fig 1, the amount of downtime is exaggerated by the data resampling.

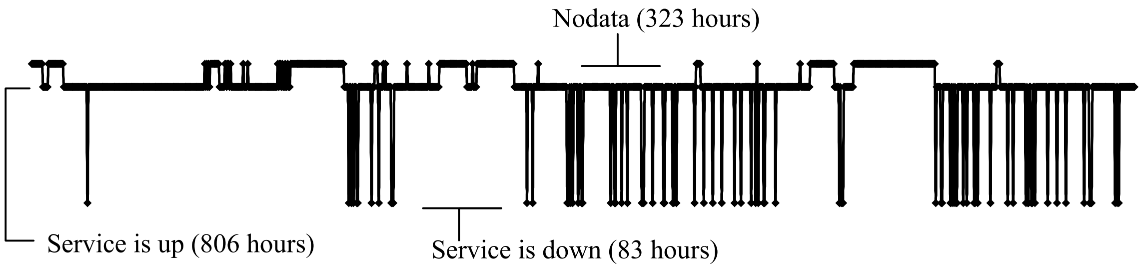



**Figure 2. Another representation of downtime, for a single WMS**. The raw data were resampled to a resolution of one point per hour. "Down" points were given priority; an hour was classified as down time if the service was unavailable at all during the hour. The horizontal axis represents 1200 hours (50 days). Adjacent points in time are connected by lines to show the patterns of reliability. As with Fig 1, the resampling and graphic representation exaggerates the total amount of down time. At full resolution, this service availability is 97.4%.

A non-graphic summary of the monitoring results is presented in Table 1. All data for public services between August 6 and September 22 were used to compute the availability percentages shown in the table. Availability is defined for each service as

$$\text{availability} = \frac{\text{'available' data points}}{\text{total data points}}$$

As noted earlier, the raw data are not continuous, so this calculation is just an estimate of the true availability. The estimate will become more accurate as the service checker itself becomes more reliable and more data are captured and analyzed.

The table shows all 39 partners that manage services that contribute publicly visible data to *The National Map* as of September 22. Note that this definition of "partner" means the USGS is in some cases a partner with itself.

The table entries are sorted in descending order of availability. See Attachment 1 for a table with more detail about the WMSs.

# 4 Discussion

## *4.1 Availability Standards*

How much down time should *The National Map* accept from a source WMS? The data summarized in Table 1 provide a starting point for discussing this question.

Even though these technologies are new for much of the GIS community, a wide variety of organizations are currently achieving WMS availabilities well above 90%. The USGS services managed by EROS Data Center operate at 98% availability and higher, so 98% might be a reasonable target to ask all partners to aim for.[4]

98% may sound like a high level of availability–and perhaps it is for this early stage of implementation–but 2% downtime equates to 15 hours per month. If all 39 services were operating at 98% availability, the probability that at least 34 of them would be available at any given time would be near-certainty (99.988%). However, the probability that all 39 would be available at any given time would be only 45%. See Attachment B for more discussion of the statistics of this problem.

What is the lowest availability we can tolerate from any WMS? When, if ever, should we remove a WMS from *The National Map* public view because it is too unreliable? The services in the last five rows of Table 1 are candidates for such an action, but at present we have no policies or procedures for making these decisions.

Such policies will be difficult to formulate. There is probably a difference between acceptable short-term and acceptable long-term reliability. Perhaps these are only two points on a continuum that should be expressed as a curve instead of one or two simple percentage statements.

There are also difficult political issues. Should we demand higher availability from a source that serves extensive and critical data, or are we willing to accept lower availability if necessary to form a partnership? Do we have different

| *id* | *service name* | *available* |
|---|---|---|
| 11 | Tahoe Pilot WMS | 99.9% |
| 147 | Kansas (RNMP-DASC) WMS | 99.9% |
| 152 | Missouri (RNMP-MSDIS) WMS | 99.9% |
| 108 | TerraServer USA | 99.8% |
| 153 | Arkansas (RNMP-CAST) WMS | 99.8% |
| 19 | Mecklenburg Pilot (meckgeo) WMS | 99.8% |
| 102 | Wake County WMS | 99.4% |
| 34 | Delaware WMS | 99.3% |
| 38 | USGS NLCD WMS (EDC) | 99.1% |
| 37 | USGS NED WMS (EDC) | 99.0% |
| 100 | Buncombe County WMS | 99.0% |
| 113 | USGS BTS Roads WMS (EDC) | 99.0% |
| 22 | USGS LANDSAT7 (EDC) WMS | 98.9% |
| 42 | USGS NHD WMS | 98.9% |
| 71 | USGS GNIS WMS (EDC) | 98.6% |
| 126 | Charlotte WMS (National Atlas hydro) | 98.6% |
| 30 | MSDIS WMS | 98.5% |
| 23 | Mecklenburg Pilot (Mick_Co) WMS | 98.4% |
| 24 | Henderson Co NC WMS | 98.3% |
| 112 | USGS GTOPO WMS (EDC) | 98.2% |
| 121 | USGS Greenness (NDVI) (TEST) | 98.2% |
| 20 | Mecklenburg Pilot (Charlotte) WMS | 97.9% |
| 122 | USGS NLCD60 WMS (TEST) | 97.9% |
| 35 | USGS Ref WMS (RMMC new) | 97.4% |
| 70 | 133 UA Ortho WMS | 97.2% |
| 59 | Story County (IA) WMS | 96.7% |
| 15 | Denver Pilot WMS | 96.5% |
| 45 | Albuquerque Pilot WMS | 96.4% |
| 17 | Utah Pilot WMS | 96.4% |
| 101 | NC CGIA WMS | 95.2% |
| 106 | Montana WMS | 94.2% |
| 114 | Cibola NF (Sandia Ranger District) WMS | 93.5% |
| 130 | Missouri Pilot (new) | 92.5% |
| 127 | BLM PLSS WMS (new) | 92.4% |
| 27 | Wash-ID Pilot WMS | 85.7% |
| 39 | MetroGIS WMS (MN) | 83.5% |
| 61 | LA (RAC -new) WMS | 76.5% |
| 21 | Mecklenburg Pilot (sid01) WMS | 70.9% |
| 44 | Minnesota State WMS (LMIC) | 48.6% |

**Table 1. Reliability of public services.**

[4] Or maybe not. The canonical reliability number in the electronic communications industry is the fabled "five nines"—99.999%—commonly equated to 5 minutes 15 seconds of downtime per year. 98% reliability would allow about 2,000 times this much downtime, 175 hours per year.

expectations for different organizations? For example, do we expect a county-run WMS to be as reliable as one run by the U.S. Forest Service? What action is appropriate if one of our own WMSs doesn't meet the standards we set for others?

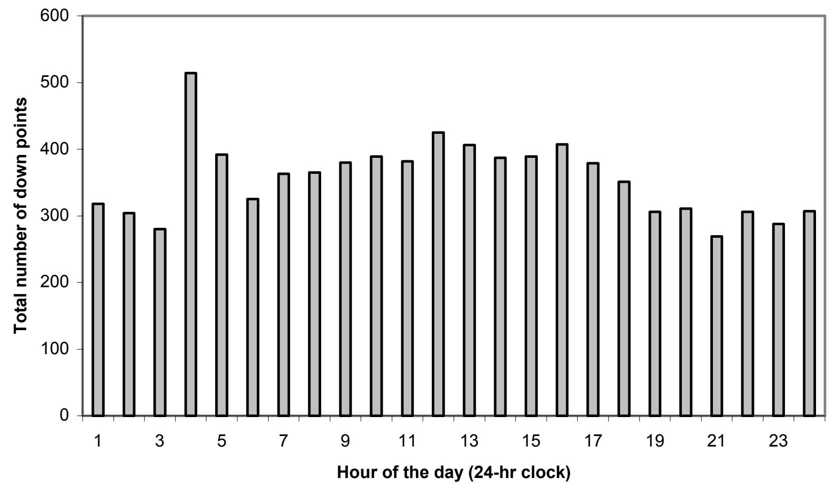



**Figure 3. Distribution of "down time" by time of day.** There is little obvious correlation between time of day and the probability that a service will be down, but no statistical analyses have yet been applied to these data.

### *4.2 Caveats and Disclaimers*

Although the data in Table 1 are encouraging, they must be interpreted with caution.

First, as noted earlier, this monitoring mechanism does not prove that non-availability is actually the fault of the source WMS.

Second, the simple availability percentage doesn't tell the whole story about a WMS. We recently had a case where a State WMS was "available" in the sense described in this report, yet was serving nothing except plain white images! For all practical purposes the service was down, but detecting this required manual effort. Though we cannot yet measure it, there is anecdotal evidence that problems of this type may be common enough to be significant.

Third, WMS availability is just one factor in a complicated equation of overall reliability. An application of *The National Map* can fail for many reasons that have nothing to do with the status of partner WMSs. A few random examples:

- Power failure in Rolla
- Power failure on east coast
- Server (in Reston) hosting Oracle public license goes down
- Server (in Rolla) hosting the Catalog goes down
- Implementing new DOI security measures inadvertently breaks public access to critical software.

## 5 Conclusions

Service checker software that is part of *The National Map* Catalog can provide continuous, high-quality data about the availability of all WMSs feeding *The National Map*.

Data collected in August and September for 39 WMSs suggest it is reasonable to expect availability percentages of over 95% from data partners. However, deciding whether or not 95% (or any other specific number) availability is adequate for the long-term needs of The National Map will be very difficult.

WMS availability is just one of many factors that contribute to the apparent availability of *The National Map*. Most of the other factors have yet to be isolated and studied, but redundancy in the infrastructure of power, hardware, and software are almost certainly important.

# 6 Additional Reading

The following two documents are available in PDF format at ftp://MCSOL10.ER.USGS.GOV/pub/graphics/tnm_partnerships. They were both written at MCMC to describe USGS-specific aspects of WMSs and the Catalog database:

"Technical Aspects of *The National Map* Data Partnerships"

"*The National Map* Catalog Database"

The following three documents are helpful for a general understanding of WMS technology. They are ordered here from least to most technical:

"Guide to Distributing Your Data Products Via WMS 1.1.1, A Tutorial for Data Providers" http://oceanesip.jpl.nasa.gov/esipde/guide.html

"OpenGIS Web Map Server Cookbook, version 1.0.0, OGC 03-050, http://www.ogcnetwork.org/docs/03-050.pdf

"Web Map Service Implementation Specification" version 1.1.1, OGC 01-068r3, http://www.opengis.org/techno/specs/01-068r3.pdf.

Some information about the "five-nines" in other parts of the computer and communications industries:

"Reality Check on Five-Nines." Gary Auden. *Business Communications Review*. http://www.bcr.com/bcrmag/2002/05/p22.asp

"Demystifying Five-Nines." Eric Krapf. *Business Communications Review.* http://www.bcr.com/bcrmag/2002/05/p06.asp

"Five Nines, by the Book." Kenneth Percy. *Network World.* http://www.nwfusion.com/columnists/2003/0414testerschoice.html

# Attachment A. List of WMSs with URLs

The table below contains the same information as Table 1 in the body of the report, except:

- An additional column contains the URL for the WMS
- The table is sorted by service ID number instead of availability

| *id* | *Service Name* | *Service URL* | *availability* |
|---|---|---|---|
| 11 | Tahoe Pilot WMS | http://mapsonline.wr.usgs.gov/ogcwms/servlet/com.esri.ogc.wms.WMSServlet?servicename=WMS_tahoe_pilot | 99.9% |
| 15 | Denver Pilot WMS | http://rockys20.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=denver | 96.5% |
| 17 | Utah Pilot WMS | http://rockys20.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=utah | 96.4% |
| 19 | Mecklenburg Pilot (meckgeo) WMS | http://ntmeckmap.co.mecklenburg.nc.us:80/servlet/com.esri.wms.Esrimap?servicename=meckgeo | 99.8% |
| 20 | Mecklenburg Pilot (Charlotte) WMS | http://gisdata.usgs.net:80/servlet/com.esri.wms.Esrimap?servicename=Charlotte | 97.9% |
| 21 | Mecklenburg Pilot (sid01) WMS | http://edcw2ks51.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=sid01 | 70.9% |
| 22 | USGS LANDSAT7 (EDC) WMS | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_LANDSAT7 | 98.9% |
| 23 | Mecklenburg Pilot (Mick_Co) WMS | http://gisdata.usgs.net:80/servlet/com.esri.wms.Esrimap?servicename=Mick_Co | 98.4% |
| 24 | Henderson Co NC WMS | http://www.gis.hendersoncountync.org:80/servlet/com.esri.wms.Esrimap?servicename=urban | 98.3% |
| 27 | Wash-ID Pilot WMS | http://inside3.uidaho.edu:80/servlet/com.esri.wms.Esrimap?servicename=WMS_idaho_wash | 85.7% |
| 30 | MSDIS WMS | http://msdis-aps.missouri.edu/servlet/com.esri.wms.Esrimap?ServiceName=msdisusgs_wms | 98.5% |
| 34 | Delaware WMS | http://datamil.udel.edu/servlet/com.esri.wms.Esrimap?servicename=datamil_tnm | 99.3% |
| 35 | USGS Ref WMS (RMMC new) | http://nmviewer.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=multinm_phase1 | 97.4% |
| 37 | USGS NED WMS (EDC) | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_NED | 99.0% |
| 38 | USGS NLCD WMS (EDC) | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_NLCD | 99.1% |
| 39 | MetroGIS WMS (MN) | http://www.datafinder.org/mapaccess/main.jsp | 83.5% |
| 42 | USGS NHD WMS | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_NHD | 98.9% |
| 44 | Minnesota State WMS (LMIC) | http://156.98.2.224/mapaccess/main.jsp | 48.6% |
| 45 | Albuquerque Pilot WMS | http://rockys20.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=albuquerque_pilot | 96.4% |
| 59 | Story County (IA) WMS | http://maps.promap.com:80/servlet/com.esri.wms.Esrimap?servicename=storywms | 96.7% |
| 61 | LA (RAC -new) WMS | http://cassini.rac.louisiana.edu:80/servlet/com.esri.wms.Esrimap?servicename=The National Map | 76.5% |
| 70 | 133 UA Ortho WMS | http://gisdata.usgs.net:80/servlet/com.esri.wms.Esrimap?servicename=133urban | 97.2% |

| | | | |
|---|---|---|---|
| 71 | USGS GNIS WMS (EDC) | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_GNIS | 98.6% |
| 100 | Buncombe County WMS | http://www.buncombegis.org:80/servlet/com.esri.wms.Esrimap?servicename=bunco | 99.0% |
| 101 | NC CGIA WMS | http://204.211.135.111:80/servlet/com.esri.wms.Esrimap?servicename=cgia_defwms | 95.2% |
| 102 | Wake County WMS | http://imaps.co.wake.nc.us:80/servlet/com.esri.wms.Esrimap?servicename=wakenc | 99.4% |
| 106 | Montana WMS | http://maps.nris.state.mt.us:8080/ogcwms/servlet/com.esri.ogc.wms.WMSServlet?SERVICENAME=natmap_mt1_svc& | 94.2% |
| 108 | TerraServer USA | http://terraservice.net/ | 99.8% |
| 112 | USGS GTOPO WMS (EDC) | http://gisdata.usgs.net:80/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_GTOPO | 98.2% |
| 113 | USGS BTS Roads WMS (EDC) | http://gisdata.usgs.net/servlet/com.esri.wms.Esrimap?servicename=USGS_WMS_BTS_Roads | 99.0% |
| 114 | Cibola NF (Sandia Ranger District) WMS | http://maps.fs.fed.us:80/servlet/com.esri.wms.Esrimap?servicename=SandiaPilot | 93.5% |
| 121 | USGS Greenness (NDVI) (TEST) | http://edcw2ks51.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?ServiceName=USGS_IVM | 98.2% |
| 122 | USGS NLCD60 WMS (TEST) | http://edcw2ks51.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?ServiceName=USGS_WMS_NLCD60 | 97.9% |
| 126 | Charlotte WMS (National Atlas hydro) | http://edcw2ks22.cr.usgs.gov:80/servlet/com.esri.wms.Esrimap?servicename=Charlotte | 98.6% |
| 127 | BLM PLSS WMS (new) | http://www.lsi.blm.gov:80/servlet/com.esri.wms.Esrimap? | 92.4% |
| 130 | Missouri Pilot (new) | http://www.esri.com | 92.5% |
| 147 | Kansas (RNMP-DASC) WMS | http://www.cast.uark.edu/ | 99.9% |
| 152 | Missouri (RNMP-MSDIS) WMS | http://mcdc.missouri.edu/ | 99.9% |
| 153 | Arkansas (RNMP-CAST) WMS | http://www.cast.uark.edu/ | 99.8% |

# Attachment B. The Binomial Distribution and Service Up-Time Probabilities

The data collected by the service checker can be used to estimate the percentage of time that a particular service is available for any arbitrary period of time. If these estimates are reasonably correct, then the binomial distribution can be used to draw inferences about the population of services.

Given $n$ services with average availability $p$ (where $p$ is between 0 and 1), the probability $P(n,r)$ that exactly $r$ services will be available at any particular time is

$$P(n,r) = \binom{n}{r} p^r (1-p)^{n-r}$$

where $\binom{n}{r}$ is the number of combinations that can be made of $n$ services taken $r$ at a time,

$$\binom{n}{r} = \frac{n(n-1)(n-2)\ldots(n-r+1)}{r(r-1)(r-2)\ldots(2)(1)}$$

The probability that $r$ **or more** services will be available at a particular time is

$$P(n,r..n) = P(n,r) + P(n,r+1) + \ldots + P(n,n)$$

Most spreadsheets implement the binomial distribution with a built-in function. In Microsoft Excel, the function is

> BINOMDIST(*r, n, p, cumulative*)
>
> where *cumulative* takes the values TRUE or FALSE. If cumulative is TRUE, then BINOMDIST returns the cumulative distribution function, which is the probability that there are at most *r* successes [services up]; if FALSE, it returns the probability mass function, which is the probability that there are exactly *r* successes.

This makes it a simple matter to simulate any desired scenario with a spreadsheet. For example, given $n$=100 services and $p$=0.98, then the probability of $r$ or more services being available is

| *r* | *P(n,r..n)* |
|---|---|
| 100 | 13.26% |
| 99 | 40.33% |
| 98 | 67.67% |
| 97 | 85.90% |
| 96 | 94.92% |
| 95 | 98.45% |
| 94 | 99.59% |
| 93 | 99.91% |
| 92 | 99.98% |
| 91 | 99.99% |

The table illustrates that if *The National Map* depends on 100 WMSs that have an average availability of 98%, then (for example) the probability that all 100 will be available at the same time is only 13%. However, it is nearly certain that at least 93 will be available at any given.

These probabilities are quite sensitive to the average service availability. If the average availability is changed to 95%, the probability that all 100 services will **ever** be available at the same time approaches zero:

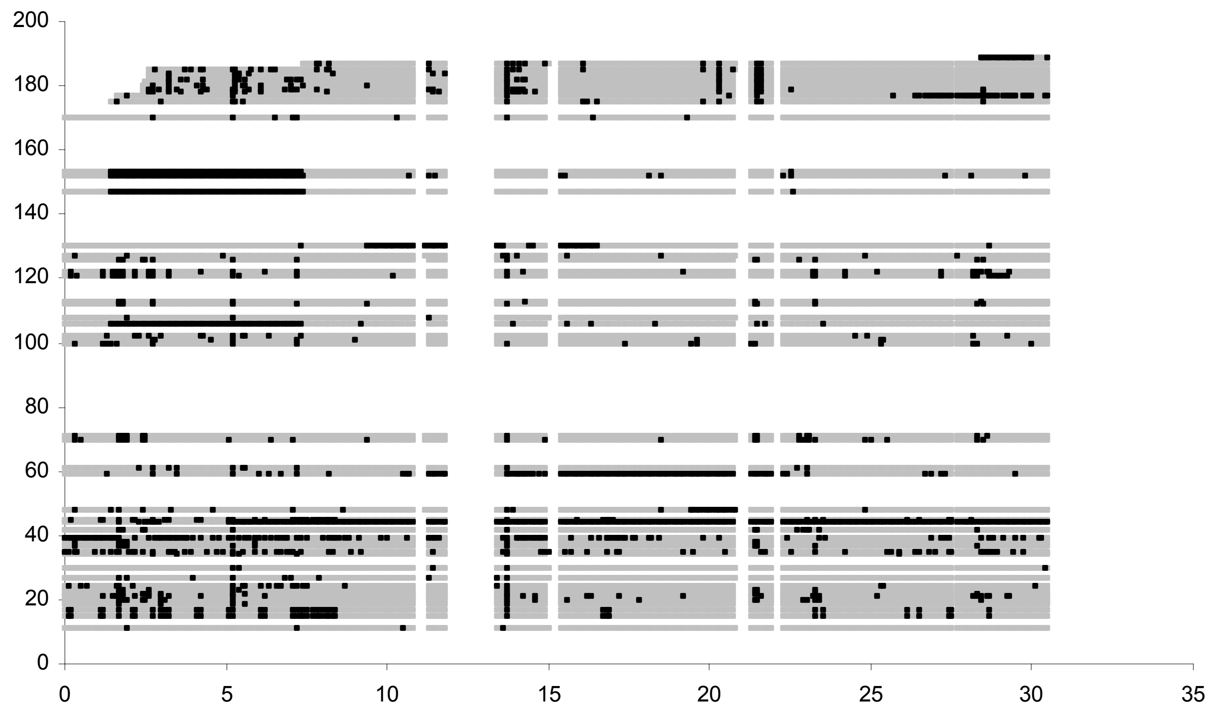
| *r* | *P(n,r..n)* |
|---|---|
| 100 | 0.59% |
| 99 | 3.71% |
| 98 | 11.83% |
| 97 | 25.78% |
| 96 | 43.60% |
| 95 | 61.60% |
| 94 | 76.60% |
| 93 | 87.20% |
| 92 | 93.69% |
| 91 | 97.18% |

The statistics of the binomial distribution assume that:

1. All outcomes are equally likely. In this application, this means that over the entire population of services, instances of downtime occur randomly.
2. All trials are independent of one another. In this application, the probability that one service will be down does not depend on the status of another service.

These assumptions are not strictly true for this study of WMSs. For example, trials are not independent because more than one service can run on the same computer hardware. This study therefore makes the weaker assumption that, unless some patterns to show otherwise can be found in the data, the strict statistical assumptions are **close enough** to being true to be useful for illustration and policy-making discussions.

# Attachment C. October 2003 update




Duplication of Figure 1 for October 2003. Several new partners were added (higher numbered ids on the Y axis). There is no obvious overall improvement in WMS reliability. The X axis is days from October 1, the Y axis is service ID numbers.

| *id* | *service* | *reliability* |
|---|---|---|
| 108 | TerraServer USA | 0.998 |
| 19 | Mecklenburg Pilot (meckgeo) WMS | 0.998 |
| 30 | MSDIS WMS | 0.998 |
| 11 | Tahoe Pilot WMS | 0.996 |
| 170 | Sedgwick County (KS) WMS | 0.996 |
| 101 | NC OneMap WMS | 0.996 |
| 127 | BLM PLSS WMS (new) | 0.996 |
| 181 | Washington DC (CUES Region 1) WMS | 0.996 |
| 34 | Delaware WMS | 0.995 |
| 183 | Washington DC (CUES Region2) WMS | 0.995 |
| 113 | USGS BTS Roads WMS (EDC) | 0.994 |
| 23 | Mecklenburg Pilot (Mick_Co) WMS | 0.994 |
| 27 | Wash-ID Pilot WMS | 0.994 |
| 61 | LA (RAC -new) WMS | 0.994 |

Table 1 equivalent, for October 2003. No statistical analyses were done to compare these data with those from August-September, but no major changes in either relative or absolute reliability are obvious.

| *id* | *service* | *reliability* |
|---|---|---|
| 184 | Washington DC (CUES 5m Hypso) WMS | 0.993 |
| 38 | USGS NLCD WMS (EDC) | 0.993 |
| 175 | Loudoun County WMS | 0.993 |
| 180 | Washington DC (CUES Buildings) WMS | 0.992 |
| 112 | USGS GTOPO WMS (EDC) | 0.992 |
| 102 | Wake County WMS | 0.991 |
| 37 | USGS NED WMS (EDC) | 0.991 |
| 22 | USGS LANDSAT7 (EDC) WMS | 0.991 |
| 182 | Washington DC (1m Hypso)(CUES) WMS | 0.990 |
| 42 | USGS NHD WMS | 0.990 |
| 71 | USGS GNIS WMS (EDC) | 0.988 |
| 24 | Henderson Co NC WMS | 0.988 |
| 178 | Washington DC (CUES 10m Hypso) WMS | 0.988 |
| 100 | Buncombe County WMS | 0.987 |
| 126 | Charlotte WMS (National Atlas hydro) | 0.987 |
| 20 | Mecklenburg Pilot (Charlotte) WMS | 0.985 |
| 179 | Washington DC (CUES Parks) WMS | 0.985 |
| 185 | Washington DC (CUES Spot Elevations) WMS | 0.983 |
| 187 | Washington DC (CUES DC Roads) WMS | 0.981 |
| 70 | 133 UA Ortho WMS | 0.978 |
| 122 | USGS NLCD60 WMS (TEST) | 0.976 |
| 21 | Mecklenburg Pilot (sid01) WMS | 0.975 |
| 121 | USGS Greenness (NDVI) (TEST) | 0.970 |
| 48 | USGS Catalog WMS | 0.970 |
| 35 | USGS Ref WMS (RMMC new) | 0.962 |
| 177 | FS Southwestern Region WMS | 0.955 |
| 17 | Utah Pilot WMS | 0.935 |
| 15 | Denver Pilot WMS | 0.934 |
| 45 | Albuquerque Pilot WMS | 0.934 |
| 130 | Missouri Pilot (new) | 0.912 |
| 39 | MetroGIS WMS (MN) | 0.858 |
| 59 | Story County (IA) WMS | 0.826 |
| 147 | Kansas (RNMP-DASC) WMS | 0.814 |
| 153 | Arkansas (RNMP-CAST) WMS | 0.813 |
| 106 | Montana WMS | 0.810 |
| 152 | Missouri (RNMP-MSDIS) WMS | 0.808 |
| 189 | FS Pike Pilot | 0.577 |
| 44 | Minnesota State WMS (LMIC) | 0.374 |